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TABLE OF CONTENTS.

ORIGINAL ARTICLES: PAGE

Decrease of Temperature with Increase of Altitude. PROFESSOR WILLIAM FERREL.... 145
Some Diurnal and Annual Oscillations of the Barometer. H. HELM CLAYTON..... 150
The Mineral Waters of Gratiot County, Michigan. I. N. BRAINERD, M. D.. 153
State Tornado Charts.—Kansas. LIEUT. JNO. P. FINLEY, Signal Service, U. S. A..... 158
Saussure on the Use of the Sling Psychrometer..... 168
Atmospheric Economy of Solar Radiation. ARTHUR SEARLE, with Comments by PROFESSOR FERREL..... 173

CORRESPONDENCE:

A Stationary Dust-Whirl. WARREN HOPKINS..... 179

CURRENT NOTES:

The Judges of the Tornado Essays 180
Himmel und Erde..... 180
A Differential Barometer for Altitudes..... 181
Locomotives and Moisture..... 181
The Chamsin. W. M. D..... 182
International Meteorological Congress..... 183
Climate of Puebla, Mexico..... 185
Repertorium für Meteorologie Band XI, St. Petersburg, 1888. F. WALDO..... 187
Royal Meteorological Society..... 190-191

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THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. VI. ANN ARBOR, AUGUST, 1889. No. 4.

ORIGINAL ARTICLES.

DECREASE OF TEMPERATURE WITH INCREASE OF ALTITUDE.

BY PROF. WILLIAM FERREL.

If the whole atmosphere were without aqueous vapor, and in such a stable state that no temperature disturbances could give rise to ascending and descending currents, and so to an interchange of air between the upper and lower strata of the atmosphere, the temperature of the air above would undoubtedly be very low in comparison with that of the earth's surface, and of the lower strata heated by conduction from the earth's surface. There would, therefore, be in this case a very rapid decrease of temperature with increase of altitude, but the rate of decrease would most probably vary greatly at different altitudes.

If the earth had no atmosphere, and a thermometer, or any body, were suspended at night at any moderate altitude above the earth's surface, its static temperature would be very low in comparison with that of the surface of the earth. If such a body were surrounded on all sides by a complete inclosure, we know that its static temperature would be that of the inclosure. But when thus suspended not very far above the earth's surface it receives from this surface, if it has a maximum radiativity, such as lampblack is usually supposed to have, only half as much radiated heat as it would from

a complete inclosure of the same temperature, and consequently its static temperature is that at which it radiates only half as much heat as it does at the temperature of the complete inclosure. To determine this temperature, therefore, it is necessary to know the relation between the radiativity of a body and its temperature. According to the law of Dulong and Petit, the temperature of a body, at all temperatures, must be diminished 90° in order to have its radiation decreased to one-half, and hence, if we suppose the temperature of the earth's surface to be 15°, which is about the mean of the whole surface, a black-bulb thermometer, or any body in which the relative radiativity and absorptivity are equal, would stand at a temperature of — 75°. But by Stefan's law, which makes the radiation increase as the fourth power of the absolute temperature, the temperature would have to be reduced 46° only in order to have half the amount of radiation, and so the body would stand at a temperature of — 31° only. So great is the difference in these two laws when extended down to temperatures far below those in the experiments from which they have been deduced. According to recent researches of the writer, the truth lies between these two laws, but nearest to the latter. The body, therefore, would probably stand at about the temperature of — 50°, and so 65° below that of the earth's surface. It is seen, therefore, that bodies a little above, and not in contact with the earth's surface, when there is no atmosphere, tend to assume, when not heated by the solar rays, a very low temperature in comparison with that of the earth's surface. And this would be sensibly the same for all bodies at altitudes not so great that the solid angle subtended by the earth would differ sensibly from that of a hemisphere, which would require the altitudes to be very great.

During the course of the night the earth's surface does not cool down very much on account of the shortness of the period and the reserve of heat below the surface, which after a sufficient vertical temperature gradient is established, comes up by conduction nearly as fast as it is radiated, so that at sunrise the temperature is nearly stationary. As the temperature of the surface falls, so does that of the body suspended above it, so

that the difference of temperature remains nearly, if not quite, the same. If the earth were surrounded by a clear atmosphere not heated by the solar rays, and its surface maintained at a given temperature, the upper part of the atmosphere would be somewhat in the condition of the suspended bodies; it would receive heat by radiation mostly from one side only, but would radiate in all directions the same as in the case of a perfect inclosure, and consequently its temperature would fall nearly as low as that of a body suspended in empty space above the earth's surface; for the amount of heat radiated from the rare strata of the atmosphere still above would be very small, and the amount conducted from the earth's surface would be sensibly nothing. The lower down in the atmosphere, however, the greater the amount of heat radiated from the air above, and so the higher the temperature, but this would still be much lower than that of the earth's surface down to where heat is received from this surface by contact and conduction.

The conditions are very nearly the same where the atmosphere receives the solar rays during the day, for the rays in passing through the clear atmosphere are but slightly absorbed, being mostly either reflected back or transmitted through to the earth's surface. Since it is only the absorbed heat which can affect the temperature, the temperature of the air above is but little increased by the solar rays, and their principal effect is upon the earth's surface and the lower strata of the atmosphere which receive heat from the surface by contact and conduction. This is lost again during the night by radiation into space, and so there are considerable diurnal inequalities of temperature at and near the earth's surface, while in the upper strata this diurnal oscillation of temperature is very small. The tendency of the solar rays, therefore, is mostly to cause a more rapid decrease of temperature with increase of elevation during the day than the night, while the diurnal average of the rate of decrease is not much affected.

Although the tendency is, while the atmosphere is in a static condition, for the upper strata to assume a very low temperature in comparison with that of the earth's surface, from which a

very rapid decrease of temperature with increase of altitude would arise, yet this, in general, never actually takes place, since this tendency is being constantly counteracted from other causes. It is well known that an unsaturated atmosphere becomes in an unstable state as soon as the vertical gradient of decreasing temperature is more than 1° for each 100 meters of ascent, and even with a much smaller gradient where the air is saturated, and that this state gives rise to ascending currents, which are manifested in ordinary rain-storms, cyclones, tornadoes, etc., and consequently to descending currents in the surrounding parts. Hence, before the vertical gradient of decreasing temperature becomes very much greater than 1° for each 100 meters, there is a bursting up of the air of the lower strata through those above, very gently, as in ordinary rains, if the gradient has not become much greater than 1° for each 100 meters before some initial disturbing cause arises, but often wtih great violence if this gradient has become very much greater before such disturbing cause takes place, and especially where this is of a very local character. If there were a continual and very rapid interchange between the upper and lower strata, it is evident the vertical gradient would never be much greater or less than 1° for each 100 meters in unsaturated air, and not so much as this where the air is saturated, as it is in ascending urrents up in the cloud regions. In the frequent inversions, therefore, of the air of the upper and lower strata of the atmosphere, arising from the various kinds of storms, the vertical gradient of decreasing temperature never becomes very much greater than 1° for each 100 meters. But the gradient, especially in the upper regions of the atmosphere, is generally much less than this on account of the heat of condensation given out in the ascending currents after the vapor has ascended to the altitude where condensation commences. By a reference to Table XIII of the appendix of Recent Advances in Meteorology, it is seen that this gradient in the ascending current here is mostly less than one-half of what it is in saturated air. But in the gradual descent of the air the tendency is to increase the gradient to that of dry air, since saturated air in its descent becomes at once un-

saturated. In the cloud region, also, especially at the upper limit, the temperature, and the regularity of the vertical gradient, may be very much affected by the absorption of the sun's heat by the cloud instead of letting it pass through mostly to the earth's surface.

Since condensation and cloud-formation take place mostly above, after the vapor has ascended to a greater or less altitude, it is evident that the general or average vertical gradient is less above in the cloud region than in the lower strata of the atmosphere, and less here during cloudy than in clear weather. And this is in accordance with the results deduced from the discussions of Glaisher's observations in his balloon ascents, according to which the gradient in clear weather was 0.98° from 0 to 1,000 feet of altitude, 0.72° from 1,000 to 2,000 feet, but only 0.46° from 5,000 to 10,000 feet of altitude. In cloudy weather the gradient was considerable less below, but nearly the same as in clear weather up at high altitudes.

The principal point which we have attempted to establish is that during settled, and especially clear, weather the conditions which determine the temperature of the atmosphere, and especially of the upper part of it, are such that the vertical temperature gradient is gradually increased until the unstable state is induced, it may be, at times, until the atmosphere becomes very unstable, when irruptions of the air of the lower strata up through the upper ones occur, ascending and descending currents and an interchange of air of the upper and lower strata take place, and the atmosphere is brought back for a time to the stable state, when settled, and perhaps fair, weather prevails again for a time, until the same unstable state and inversions occur again; so that the general vertical gradients of temperature are such as do not vary much from that of incipient instability of the atmosphere, which would exist if there was a very rapid interchange of air between the upper and lower strata, these gradients being sometimes greater, when the atmosphere becomes unstable, and then less, when the weather is settled and fair. If the atmosphere were of such a nature that a vertical gradient of 1° for each 50 meters instead of each 100 meters

would be caused by ascending and descending currents, the unstable state would, no doubt, be still induced under the conditions determining the temperature, but not so readily, and then the general vertical temperature gradient would be about twice as great.

In the annual changes of the seasons the earth's surface and the lower strata of the atmosphere become warmed up faster in spring and early summer than the air of the upper strata, so that at this season the unstable state is more readily induced, and the various atmospheric disturbances prevail more than during the fall, when the earth cools faster than the air above, and so the unstable state is not so readily produced, and therefore more settled weather generally prevails.

SOME DIURNAL AND ANNUAL OSCILLATIONS OF THE BAROMETER.

By H. Helm Clayton.

In the second volume of Gen. Greely's report of the Arctic Expedition to Lady Franklin Bay, it is pointed out on page 169 that if the diurnal change in pressure observed at the five arctic stations, Fort Conger, Point Barrow, Spitzbergen, Jan. Mayen, Sagastyr, all north of 70° latitude, but differing widely in longitude, be plotted in simultaneous time, the maxima and minima of all the curves show a striking coincidence with each other; while if plotted in local time they are widely divergent. The curves when all plotted in Washington mean time show a chief maximum about 6 A. M., a minimum about noon, a secondary maximum about 5 P. M., and a chief minimum about midnight. It seems interesting in this connection to notice that the chief maximum which occurs at 6 A. M., Washington time, is coincident with the time of greatest daily temperature over the great continental area composed of Europe, Asia, and Northern Africa; the secondary minimum occurs just as the noon-day sun has crossed the Atlantic Ocean; the secondary maximum occurs at the time of greatest daily temperature in the center of the

American continent; and the chief minimum occurs immediately after the time the noon-day sun has crossed the Pacific Ocean. It is shown in Scott's *Meteorology*, page 89, that a very decided minimum of pressure occurs over the Asiatic continent about the warmest part of the day. It is hence necessary to assume that at this time of day there is an overflow of air from this region toward surrounding regions, namely, toward the pole and toward the oceans. This seems to explain the maximum pressure at the poles. On the other hand, when the sun is vertical over the ocean the air is cooling and the pressure rising over the Asiatic continent, indicating a flow of air from surrounding regions. The air which flows toward this region from the pole is not replaced by air flowing from the ocean toward the pole, because the atmosphere over the ocean is but little heated by the sun; and hence at this time a minimum of pressure occurs a the pole. The secondary maximum and chief minimum are probably explained in the same manner by the heating and expansion of the air over the American continent, and the approximate absence of this effect over the Pacific ocean.

This rapid interchange of effects from continent to continent is also in line with what is becoming more apparent every day namely, that atmospheric disturbances at any place are connected with phenomena occurring over immense areas. Storms and anticyclones are not in general the result of the effect of local heating or cooling within their areas of action, but are rather mechanical and dynamic effects of continental and oceanic heating and cooling. In the future, when weather forecasting shall have become more exact, and for longer intervals in advance, there can scarcely be any doubt that the weather forcaster will make use of all of the available weather observations in the northern hemisphere; and perhaps use observations from all over the world. Already in Europe, where scientific weather forecasting is more advanced than in America, they appreciate the importance of such knowledge, and are having telegrams concerning the weather in America sent to them each day.

Another fact brought out in the report of the Lady Franklin Bay Expedition, is that an annual maximum of barometric pres-

sure, beginning in the arctic region in April, occurs successively later as one advances southward across the Atlantic ocean and the western shores of Europe, until the equatorial region is reached, where the annual maximum pressure of the year occurs in August. On the other hand, an annual barometric minimum of pressure, beginning with the southern parts of the continents of North America and Asia in May and June, advances northward and covers the arctic region in July and August. These facts also appear explicable by the relative heating and cooling of the continents and oceans. When the temperature over any region is rising, there is known to be a tendency for the air to expand and overflow toward adjacent regions. It is also known that curves representing the annual sweep of the temperature begin to rise in the southern part of the great continents before they do in the arctic region, where the minimum temperature of the year occurs in February. Hence, in late winter and early spring there is an increased tendency for the air to flow toward the pole, and this probably culminates with the maximum pressure near the pole in April, after which the continents become warmer than the ocean, and the expanding air over the continents tends to overflow toward the ocean. Hence, in May the place of maximum pressure for the year is displaced from the pole toward the North Atlantic Ocean. At this time the temperature is rising rapidly in the arctic regions, and the contrast in temperature between the continents and oceans is increasing, so that in June we find an annual maximum of pressure over the center of both the Atlantic and Pacific Oceans,* and a minimum over the southern parts of the adjacent continents. At this time of year the temperature is rising much more rapidly in and near the arctic region than near the equator, and hence there is a relative expansion of the air from the pole toward the equator, until in July and August the minimum pressure of the year is reached in the arctic region, and the northern part of the continents; while a maximum of pressure occurs near the equator. In the winter time, when the temper-

*The chief maximum of the year, however, occurs over the middle Atlantic in February, for other reasons.

ature is lowest, the maximum pressure of the year is found over the continents, and in the main over the entire northern hemisphere, except over the North Atlantic and Pacific Oceans, where minimum pressures are found, evidently because the temperature at these places is relatively much higher than over the adjacent continents. Of course, to thoroughly explain these phenomena, the effects of the earth's rotation and the centrifugal force of the air would have to be considered; but as well as the writer understands these laws, the effects of the earth's rotation would not be to prevent a rise of pressure where the temperature was falling and a fall of pressure where the temperature was rising, but merely to check these tendencies, and when the contrast of temperature was fully established, to cause a redistribution of the pressure.

BLUE HILL OBSERVATORY, READVILLE, MASS., March 20, 1889.

THE MINERAL WATERS OF GRATIOT COUNTY, MICHIGAN.

BY I. N. BRAINERD, M. D.

Health resorts in Michigan are somewhat numerous; and that physicians and their patients may have some knowledge of these places, other than that which is obtainable from advertisements, is highly desirable. Having knowledge of the mineral waters of Gratiot county, I have imposed upon myself the task of setting forth their virtues.

There are two medical sanitariums in Gratiot county—one at St. Louis, and one at Alma. The published analysis of the St. Louis water is follows:

Carbonate of Soda, ...	7.684 grains to the pint.
Carbonate of Magnesia, Carbonate of Iron, . . . Carbonate of Lime, . .	5.019 grains to the pint.
Sulphate of Lime, ...	6.925 grains to the pint.
Silicate of Lime, ...	——
Silica, ...	——

The carbonates of soda, lime and magnesia are all alkaline carbonates, and as such are all ant-acid, and increase the alkalinity of the blood, and render neutral or alkaline the urine. In acid dyspepsia either of these carbonates is efficient in securing

immediate relief, but the after effect is to increase the production of acid. The acid diarrhœa of children can be relieved by the carbonate of soda, and it is one of the chief remedies in the alkaline treatment of rheumatism.

Carbonate of magnesium is a mild and agreeable laxative for children and pregnant women, provided it enters into combination with acids in the stomach. Meeting with hydrochloric acid it forms magnesium chloride, which is a laxative. Without this chemical reaction it is not a laxative. To insure this decomposition and recomposition, it is a good plan to follow the medicine with a glass of lemonade. This will make the citrate of magnesium, which is a well-known laxative, and set free carbonic anhydride, which is a sedative and anæsthetic to the gastric mucous membrane. The carbonate of lime (limestone) reënforces that substance in the blood. Iron, though the carbonate is not the best preparation, promotes both appetite and digestion. Some authorities claim that its therapeutic value depends almost wholly upon its power to promote digestion. It increases the number of red cells and the quantity of their hæmatin. Rheumatism, in the anæmic, is benefitted by iron, the tincture of the chloride being the best preparation for this affection. The carbonate found in the water is converted into chloride in the stomach, but is not, of course, made into a tincture there. The tincture is also used in the treatment of erysipelas and diphtheria. Scrofula, strumous enlargement of the cervical, inguinal and mesenteric glands and rickets should be treated with the iodide of iron, but would be somewhat benefitted by the carbonate. Neuralgia, chorea and disorders of the mind depending upon anæmia call for iron. The sulphate of lime (gypsum), silica (quartz) and silicate of iron (in rocks and glass) have no therapeutic value.

The St. Louis springs should be classed among the "alkaline mineral springs," and their water somewhat resembles the celebrated Vichy water of France. This water taken before meals, will increase the flow of gastric juice, and hence be serviceable in atonic dyspepsia. From its laxative properties, it will relieve chronic constipation and hæmorrhoids dependent thereon.

Obesity would probably be reduced by it. Rheumatism and gout will be especially benefitted by these alkaline waters. The lithic-acid diathesis can be cured by the long continued use of alkaline waters. Diabetes in the obese is wonderfully benefitted by alkaline waters combined with a proper diet. Chronic skin diseases and erysipelas would probably be benefitted here. Anæmia and diseases resulting therefrom ought to be benefitted by this water.

It is to be regretted that the managers style this water "magnetic." Every scientist knows that water is not and cannot be made magnetic. The magnetism is produced by terrestrial currents in the vertical iron tube through which the water flows.

The Alma water contains in grains per pint, according to the chemist's report:

	First Well.	Second Well.	Third Well.
Sodium Chloride	9.27	1731.85	1160.26
Calcium Chloride	1.12	314.82	1543.86
Magnesium Chlor.	.....	201.79	161 59
Bicarb. Iron	.....	11.96	8.20
Calcium Carb.	1.19	11.82	.....
Magnes. Carb.	.48	5.15	.....
Potas. Chloride	.08	55.27	277.60
Calcium Sulphate	1.38	.63	.....
Sodium Bromide	.. ..	27.16	118.21
Sodium Iodide	.....	19.12	103.70
Silica	.26	.....	.....
Alumina	.44	.....	.....
Ferric Oxide	.02	.....	.....

It is believed that the bromide and iodide of sodium are too large.

Chloride of sodium has, unquestionably, an important office in the economy, and it is equally certain that we get enough of it, and sometimes too much in our food for all ordinary purposes. If there were a lack of the fluidity of the blood-albumen or of the fibrine, sodium chloride in excess of our ordinary food-allowance would do good. Its deprivation is a great injury. In association with the other salts in this water, it adds to the common saline property and doubtless increases its efficiency.

Calcium chloride is an alterative of no mean value. "Recent studies of the therapeutical actions of chloride of calcium have shown it to possess the remarkable property of an antagonist or antidote to the strumous constitution. * * * It has been shown * * * that under its use enlarged and cheesy lymphatics gradu-

ally resume their normal condition, tubercular deposits undergo a process of calcification, and ulcerating cavities discharge their contents and cicatrize. It can not, of course, be asserted that such surprising changes frequently occur, but that they do sometimes take place, clinical experience has proved. From this point of view, then, chloride of calcium assumes a high degree of importance."—(Bartholow). It is useful in the disordered secretions of strumous children, and in colliquative diarrhœa. "According to the published observations of Begbie, Coghill and Bell, we possess no agent so valuable in the wasting diseases of children of strumous origin, in glandular enlargements, etc. The testimony which has lately been published in respect to the curative power of chloride of calcium in consumption is certainly very striking, and especially in those cases succeeding to glandular enlargements heretofore so little amenable to treatment. According to Rodolfe, chloride of calcium cures corea speedily."—(Bartholow). But there is one hundred times too much of it in the third well.

Magnesium chloride is not an officinal remedy, but is a laxative. It is the chloride into which the carbonate is oftenest converted in the stomach.

Sodium bromide is a sedative, much resembling the other bromides. It has the greatest effect of all upon the pulse, respiration and temperature, is second in its effects as a hypnotic, and is least in quieting reflexes. It is useful in relieving nervous and hyperæmic headaches, and to induce sleep. It may be used to suppress increased heart action from irritation of the sympathetic system, to relieve poisoning from mercury, copper and lead, neuralgia, sick headache, epilepsy, peripheral vasomotor disturbances, and a score of other affections.

Sodium iodide is similar to potassium iodide in its therapeutic properties, but is less efficient.

For a description of the other substances found in this water see paragraphs above.

As a whole, this water must be classed among the "saline mineral waters," and it somewhat resembles the Kissengen waters of Bavaria. It is useful in scrofula, dyspepsia, hepatic obstruc-

tion, diabetes, constipation, rheumatism, gout, and pelvic troubles in females.

The managers of this well are also guilty of the "magnetic" nonsense, and further advertise that the water has "a temperature of 135 to 150 degrees." Why this great variation? Five or six degrees is sufficient for the seasonal changes. Which is it? Is it 135, or is it 150? or is it neither? Let us see. The temperature of the interior of the earth increases one degree for every fifty feet of descent after the first 100 feet. This well is nearly 2,900 feet deep. Subtracting the first 100 feet, we have 2,800. This number contains 50 56 times. That is, the bottom of that well is 56° warmer than the top. By actual test I find that the water flowing from a 100-foot well has a temperature of 48°. $56° + 48° = 104°$. That water cannot, therefore, be above 104°, or thereabouts, and by the time it has flowed through that half-mile of pipe it will be below that. The "Hot Springs" of Virginia have a temperature of 100° to 106°.

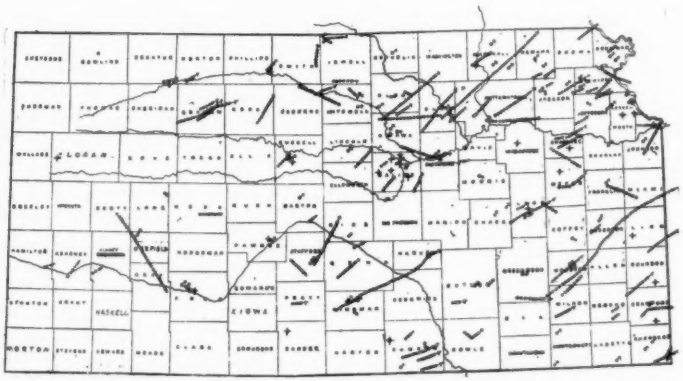
There is a score of other mineral wells in Alma; but I will mention only one — that of L. D. Rodman. I mention it because its water is being put upon the market. It contains

Bicarbonate of iron;
Sulphate of lime;
Chloride of sodium;
Sulphate of magnesium;
Carbonate of lime;
Carbonate of magnesium;
Oxide of aluminum.

This is saline water, and resembles somewhat the "Eureka" well, among the "Saratoga Springs" in New York. This water contains sulphate of magnesium (Epsom salt) and is more laxative than the others. It will be found useful in constipation, plethora of tha abdominal viscera, hæmorrhoids, obesity, gout and rheumatism. The oxide of alumina is of no value. In crystalline form it is the gems, sapphire, ruby, oriental emerald, oriental topaz and oriental amethyst.

The properties of the other subtances are described above.

ALMA, MICH., June 23, 1889.



TORNADOES IN KANSAS.

STATE TORNADO CHARTS.—KANSAS.

By LIEUT. JNO. P. FINLEY, Signal Service, U S. A.

TABLE I.—*Tornadoes in Kansas.*

Period of observation, 30 years, 1859-1888.
Total number of storms, 182.
Year of greatest frequency, 1881,—22 storms.
Average yearly frequency,—13 storms.
Year in past (10) ten years no report of storms,—none.
Month of greatest frequency, May,—48 storms.
Day of greatest frequency, May 30th,—10 storms.
Hour of greatest frequency, 3 to 4 P. M.
Months without storms, January, October and December.
Prevailing direction of storm movement, NE.
Region of maximum storm frequency, central and eastern portions.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of Kansas for a period of 30 years, from 1859 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Franklin and Miami	June —.	1859	3 a. m.	SE.	.....	165.
Ottawa	June 20.	1859	Afternoon.	NE	.....	.....
Doniphan	July 4.	1860	5 p. m.	ENE.	Funnel.	.....
Shawnee	July 31.	1860	5 p. m.	SE.	Inverted Funnel.	2,500.
Marshall	"	1860	3:30 p. m	NE.	Funnel.	.....
Doniphan	June 16.	1863	Afternoon.	NE.	"	.....
Republic	November 8.	1870	Afternoon.	NE.	Cone.	.....
Saline	April —.	1872	.....	E	.....	.....
Cloud	June 28.	1873	3 p. m.	E.	Funnel.	.....
Osage	April 4.	1874	.....	.....	.....	.....
Butler	June 22.	1874	Afternoon.	NE.	Funnel.	.....
Montgomery	June 26.	1874	Afternoon.	NE.	"	.....
Pawnee	March 5.	1876	.....	.....	"	.....
Ford	April 26.	1876	.....	.....	.....	.....
Leavenworth	May 6.	1876	3:15 a. m.	NE.	Funnel.	.....
Ford	May 13.	1876	.....	.....	.....	.....
Saline	June 6.	1876	3:30 p. m.	NE.	Funnel.	.....
Saline	"	1876	Afternoon	NE.	"	.....
Saline	"	1876	Afternoon.	NNE.	"	.....
Lincoln	"	1876	Afternoon.	NE.	"	.....
Saline	June 7.	1876	2:45 p. m.	NNE.	"	200.
Saline	June 12.	1876	.....	.....	.....	.....
Ford	June 13.	1876	.....	.....	.....	.....
Bourbon	June 15.	1876	.....	.....	.....	.....
Ford	April 22	1877	Afternoon.	NE.	Funnel.	.....
Ottawa	May 18.	1877	Afternoon.	E.	.....	.....
Saline	"	1877	Afternoon	NE.	.....	.....
Cloud	June 12.	1877	Afternoon	SE.	.....	.....
Leavenworth	August 25.	1877	Afternoon.	.....	.....	.....
Cherokee	March 1.	1878	5 p. m	NE.	.....	.....
Marshall	April 5.	1878	5 p. m.	.....	.....	.....
Chase	April 13.	1878	Afternoon	ENE.	Funnel.	.....
Leavenworth	April 17.	1878	Afternoon.	NE.	.....	.....
Leavenworth and Jefferson	May 25.	1878	4 p. m.	NE	"Huge serpent."	.....
Marshall	May 31.	1878	5:30 p. m.	NE	.....	40.
Brown	May 29	1879	6 p. m.	NE.	.....	.....
Ottawa	May 30.	1879	3 p. m.	NNE.	Funnel.	3,960.

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Ottawa	May 30.	1879	3 p. m.	NE.	Funnel.	150 to 3,000.
Marshall	"	1879	6:30 p. m.	NE.	Inverted cone.	100 to 300.
Marshall	"	1879	5:30 p. m.	NE.	Funnel.	250 to 4,000.
Ellsworth and Lincoln	"	1879	2:30 p. m.	NE.	"	600.
Riley	"	1879	6 p. m.	NE.	"	160 to 3,500.
Ottawa	"	1879	4 p. m.	NE.	"	60 to 360
Clay	"	1879	5:30 p. m.	NE.	"	400 to 1,000.
Cloud	"	1879	3:30 p. m.	NE	"	800 to 1,280.
Saline	June —.	1879	6 p. m.	.....	.....	.....
Ottawa	June 10.	1879	Evening.	E.	.....	1,800 to 3,000.
Mitchell	"	1879	Afternoon.	SE.	.....	.....
Leavenworth	"	1879	Afternoon.	NE.	.....	.....
Douglas	"	1879	5 p. m.	NE.	Funnel.	.....
Cloud	June 12.	1879	Afternoon.	NE.	.....	.....
Stafford	July 28.	1879	.....	.....	.....	.....
Cherokee	April —.	1880	.....	NE.	Balloon.	.....
Franklin	April 2.	1880	6 p. m.	NE.	Funnel.	Narrow.
Crawford	"	1880	7 p. m.	ENE.	.....	50 to 825.
Johnson	April 18.	1880	4:30 p. m.	NE.	.....	.....
Woodson	May 9.	1880	5 p. m.	NE.	Serpent.	.....
Ness	May 19.	1880	3 p. m.	E.	.....	2,640.
Saline	June 5.	1880	.....	.....	.....	.....
Lane	August 15.	1880	3 p. m.	NNE.	Funnel.	200
Smith	March 10.	1881	4:15 p. m.	N	"	45 to 250.
Cherokee	March 16.	1881	a. m.	NE.	Hour-glass.	500 to 1,000.
Cherokee	April 1.	1881	12:10 p. m.	NE.	.....	900.
Chase	April 30.	1881	6 p. m.	NE.	.....	300 to 500.
Clay	May 13.	1881	Afternoon.	NE.	Funnel.	.....
Woodson	May 16.	1881	.....	NE.	"	.....
Lane	June 7.	1881	3 p. m.	SE.	"	.....
Osborne	June 9.	1881	5:30 p. m.	SE.	"	456 to 660.
Morris	"	1881	5 p. m.	SE.	.....	.....
Ottawa and Dickinson	"	1881	5 p. m.	E 20° S.	Funnel.	700.
Mitchell	"	1881	4 p. m.	SE.	"	495.
Lyon	June 11.	1881	4 p. m.	.....	"	1,320 to 5 280.
Sumner	June 12.	1881	4 p. m.	NE.	"	140.
Osage	"	1881	5 p. m.	NE.	"	30 to 5,280.
Cowley	"	1881	4:30 p. m.	E.	"	400 to 1,500.
Lyon and Osage	"	1881	4 p. m.	SE.	"	165 to 330.

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Saline	September 1.	1881	4 p. m.	NE.	Balloon.	
Sumner	September 29.	1881	Afternoon.	NE.	Funnel.	
Riley	"	1881	6 p. m.	NE.		
Nemaha	"	1881	6 p. m.	NE.		
Dickinson	"	1881	About noon.	NE.		
Lyon and Woodson	"	1881	6:30 p. m.	SSE.	Funnel.	80 to 300.
Stafford and Rice	April 5.	1882	4 p. m.	E 60° N.	"	600 to 1,500.
Saline	"	1882	5:50 p. m.	NE.	"	
Reno	"	1882	4 p. m.	NNE.	"	90 to 450.
Clay	April 6.	1882	5 p. m.		"	
Butler	April 7.	1882	10:30 p. m.	NE.		
Crawford	May 12.	1882				
Linn	June 7.	1882	4 p. m.		Funnel.	
Anderson	June 14.	1882	3 p. m.	ENE.	Cone.	450 to 1,320.
Greenwood	July 16.	1882	Morning.	E.		
Shawnee	August 6.	1882	10:40 a. m.		Funnel.	
Russell	August 27.	1882	10:35 p. m.	NE.	Whirlwind.	50.
Wabaunsee	April 19	1883	Night.			
Barbour	April 27.	1883	11:30 p. m.			
Doniphan	May 13.	1883			Funnel.	
Wyandott and Johnson	"	1883	4:30 p. m.	NE.	"	150.
Labette and Cherokee	"	1883	6 p. m.	NE.	"	40.
Riley and Pottawatomie	June 11.	1883	10:25 p. m.	NE.		
Jefferson	"	1883	11:32 p. m.	SE.	Funnel.	900.
Jackson	July 10.	1883	10 a. m.	SW ?	"	400.
Jackson	"	1883	10 a. m.	S. ?	"	400.
Sumner	July 16.	1883	5 p. m.	S	Cone.	75.
Decatur	August 14.	1883	About 3:30 p. m.	S. ?	Funnel.	
Anderson	April 26.	1884	4 p. m.	NE.	"	20 to 300.
Phillips and Smith	"	1884	2 p. m.	NE.	Truncated cone.	
Pawnee	April 28.	1884	9 p. m.	NE.	Funnel.	
Russell	"	1884	5:15 p. m.		Inverted cone.	20.
Montgomery	May 20.	1884	3:15 p. m.	NE.	Funnel.	
Russell	May 30.	1884	4 p. m.	NE.	"	
Jewell	June 14.	1884		NE.	"	
Jewell	July 12.	1884		E.	"	
Barton	July 18.	1884	8:45 p. m.	NE.	"	
Jewell	July 20.	1884		SE.		

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Russell	July 26.	1884	7:15 p. m.	NE.	Funnel.	.....
Scott, Lane, Hodgeman and Ford	"	1884	7:15 p. m.	SE.	"	.....
Shawnee	August 24.	1884	.....	.....	Elephant's trunk.	150.
Montgomery	September 26	1884	.....	NE	Serpent.	.....
Rice	April 21.	1885	2 a. m.	NE.	.....	300.
Mitchell	April 29.	1885	4 p. m.	E	Funnel.	30.
Rooks.	May 15.	1885	4 p. m.	NNE.	"	1,320 to 2,640.
Kingman	"	1885	5 p. m	NE.	"	330.
Phillips	May 16.	1885	4 p. m.	.....	"	.....
Kingman	"	1885	6 p. m.	NE.	"	.....
Nemaha	May 27.	1885	11:30 a. m.	E 40° N.	"	330.
Marshall	"	1885	10:40 a. m.	NE.	.....	15.
Jackson	"	1885	12 m.	NE.	.....	3,000.
Jefferson	"	1885	12:15 p. m.	NE.	Funnel.	30.
Atchison	"	1885	12:30 p. m.	NE.	"	.....
Kingman	June 19.	1885	1 a. m.	SE	"	.....
Leavenworth	June 20.	1885	Night.	.....	.....	.....
Stafford	"	1885	Evening.	SE	Funnel.	3,960.
Stafford	July 1.	1885	3 p. m	NE.	"	100 to 200.
Jewell	July 26.	1885	5 p. m.	NE	.....	.....
Atchison	August 5.	1885	1:25 p. m.	E 10° N.	Funnel.	.....
Nemaha	April 14.	1886	Night.	NE	"	.....
Nemaha	"	1886	4 p. m.	N 40° E.	"	495 to 875
Jackson	"	1886	4 p. m.	N 40° E.	"	495 to 850.
Saline	April 22.	1886	Afternoon.	.....	.....	.....
Neosho	May 6.	1886	2 p. m.	NE.	Funnel.	.....
Lyon	"	1886	Afternoon.	NE.	"Waterspout."	.....
Barton	"	1886	Afternoon.	NE.	.....	.....
Neosho	"	1886	4 p. m.	NNE.	Funnel.	.....
Jefferson	May 9.	1886	Afternoon.	NE.	"	600.
Jefferson	May 11.	1886	11 a. m.	NE.	"	.....
Atchison	"	1886	11:45 a. m.	.....	.....	.....
Atchison	"	1886	10:30 a. m.	NE.	Balloon.	2,640 to 5,280.
Jefferson	May 14.	1886	10 a. m.	ESE.	.....	.....
Russell	May 25.	1886	Afternoon.	SE.	Funnel.	.....
Reno	July 19.	1886	6 p. m.	Easterly.	.....	.....
Finney	"	1886	5 p. m.	NE.	.....	.....
Hamilton	August 5.	1886	Evening.	Easterly.	.....	1,320 to 2,640.

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Jewell	February 17.	1887	2 p. m.	E.	.....	.....
Linn	April 21.	1887	5:30 p. m.	ENE.	Funnel.	600 to 2,640.
Atchison	April 22.	1887	2:30 p. m.	NE.	"	.....
Woodson	"	1887	Morning.	NE.	.....	.....
Anderson	May 16.	1887	2 p. m.	NE.	Funnel.	.....
Clay	May 22.	1887	6:45 p. m.	NE.	"	.....
Lyon	July 19.	1887	4 p. m.	NE.	"	.....
Shawnee	July 21.	1887	8:40 p. m.	E.	"	1,320 to 2,640.
Graham	August 4.	1887	8 p. m.	Easterly.	"	1,320 to 7,920.
Jefferson	"	1887	5 p. m.	NE.	"	2,640.
Pottawatomie	"	1887	5 p. m.	NE.	"	Narrow.
Cherokee	August 10.	1887	6 p. m.	NE.	"	"
Sedgwick, Reno and Kingman	March 1.	1888	5:30 p. m.	N 55° E.	"	"
Lyon	"	1888	7 p. m.	Easterly.	Globular.	"
Pratt	April 26.	1888	Afternoon.	Easterly.	Funnel.	"
Graham	"	1888	Evening.	Easterly.	.....	"
Sumner	May 22.	1888	Afternoon.	Easterly.	.....	"
Mitchell	June 19.	1888	5:15 p. m.	NE.	Funnel.	"
Shawnee	August 5.	1888	Night.	Easterly.	.....	"
Norton	"	1888	6 p. m.	NE.	Funnel.	"
Graham	"	1888	5:30 p. m.	NE.	"	"
Decatur	"	1888	6 p. m.	Easterly.	"	"
Sumner	August 6.	1888	7 p. m.	NE.	"	"
Greenwood	"	1888	6:30 p. m.	Easterly.	"	1,320.
Wilson	"	1888	6 p. m.	NE.	"	2,640.
Sumner	"	1888	7:30 p. m.	NE.	"	800 to 1,000.
Butler	"	1888	Evening.	Easterly.	"	Narrow.
Sumner	August 8.	1888	7 p. m.	NE.	"	1,320.
Dickinson	November 7.	1888	6:40 p. m.	Easterly.	"	500 to 1,200.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Kansas.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January		0	0
February	17	1	1
March	$(1)^3$, 5, 10, and 16	4	6
April	1, $(2)^2$, 4, $(5)^4$, 6, 7, 13, $(14)^3$, 17, 18, 19, $(21)^2$, $(22)^4$, $(26)^5$, 27, $(28)^2$, 29, 30, $(—)^2$	22	35
May	$(6)^5$ $(9)^2$, $(11)^3$, 12, $(13)^5$, 14, $(15)^2$, $(16)^4$, $(18)^2$, 19, 20, $(22)^2$, $(25)^2$, $(27)^5$, 29, $(30)^{10}$, and 31	18	48
June	5, $(6)^4$, $(7)^3$, $(9)^4$, $(10)^4$, $(11)^3$, $(12)^7$, 13, $(14)^2$, 15, 16, $(19)^3$, $(20)^3$, 22, 26, 28, $(—)^2$	17	41
July	1, 4, $(10)^3$, 12, $(16)^2$, 18, $(19)^3$, 20, 21, $(26)^3$, 28, $(31)^2$	13	20
August	$(4)^3$, $(5)^6$, $(6)^6$, 8, 10, 14, 15, 24, 25, 27	8	22
September	1, 26, $(29)^5$	3	7
October		0	0
November	7, 8	2	2
December		0	0
Total		88	182

TORNADOES IN INDIAN TERRITORY.

STATE TORNADO CHARTS.—INDIAN TERRITORY.

By LIEUT. JNO. P. FINLEY, Signal Service, U. S. A.

TABLE I.—*Tornadoes in Indian Territory.*

Period of observation, 14 years, 1875–1888.

Total number of storms, 21.

Year of greatest frequency, 1885,—4 storms.

Year in past ten (10) years no report of storms, none.

Average yearly frequency, 1.5.

Months of greatest frequency, April and May,—7 storms each.

Days of greatest frequency, April 20, 25, and May 26, 28,—2 storms each.

Hour of greatest frequency, 6:30 to 7 P. M.

Months without storms, January, February, September, October and December.

Prevailing direction of storm movement, NE.

Region of maximum storm frequency, Eastern and south Central.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in Indian Territory for a period of 14 years, from 1875 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Cherokee Nation	May 25.	1875	Afternoon.	.....	.....	Narrow.
Cherokee Nation	June 27.	1879	Afternoon.	Easterly.	.....	"
Choctaw Nation	November 8.	1879	2:30 p. m.	NE.	Funnel.	"
Choctaw Nation	May 28.	1880	10:30 p. m.	NE.	.....	"
Choctaw Nation	June 11.	1881	6 p. m.	NE.	Funnel.	"
Chickasaw and Choctaw Nations	May 8.	1882	6:15 p. m.	NE.	"	1,320.
Choctaw Nation	May 28.	1882	Afternoon.	NE.	"	900 to 1,500
Chickasaw Nation	May 17.	1883	10 a. m.	NE.	"	Narrow.
Chickasaw Nation	April 30.	1884	3:20 p. m.	NE.	"	2,640.
Cherokee Nation	July 27.	1884	8 p. m.	ESE.	"	800 to 1,200.
Chickasaw Nation	August 1.	1884	7 a. m.	NE.	"	1,320.
Chickasaw Nation	March 11.	1885	5 p. m.	NE.	"	Narrow.
Kiowa and Comanche Nations	April 20.	1885	9:10 p. m.	NE.	"	2,640.
Chickasaw Nation	April 21.	1885	6 p. m.	NE.	"	1,320.
Kiowa and Comanche Nations	April 20.	1885	11 p. m.	NE.	.....	2,640.
Choctaw Nation	April 25.	1886	6:30 p. m.	NE.	Funnel.	1,000 to 1,200.
Choctaw Nation	"	1886	8 p. m.	NE.	"	1,320.
Kiowa and Comanche Nations	April 29.	1887	8 p. m.	NE.	"	5,000 to 8,000.
Chickasaw Nation	May 26.	1888	3:30 p. m.	NE.	"	2,640.
Cherokee Nation	"	1888	6:30 p. m.	NE.	"	Narrow.
Cherokee Nation	June 2.	1888	Afternoon.	NE.	"	1,320.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Indian Territory.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January		0	0
February		0	0
March	11	1	1
April	(20)², 21, (25)², 29, 30	5	7
May	8, 17, 25, (26)², (28)²	5	7
June	2, 11, 27	3	3
July	27	1	1
August	1	1	1
September		0	0
October		0	0
November	8	1	1
December		0	0
Total		17	21

NOTE.—The blank (—) signifies date missing.

SAUSSURE ON THE USE OF THE SLING PSYCHROMETER.

The first recorded observations with the wet bulb thermometer, whirled or slung rapidly around the head of the observer, are those by Saussure in 1788, on the Col du Géant. From these has resulted the modern use of the sling psychrometer.

The following is a translation by Sergeant G. E. Curtis of the original remarks of Saussure extracted from "Voyages dans les Alpes, 8vo., 1796, Chapter VIII."

Evaporation. pp. 438–449.

2063. Whenever water evaporates slowly, the cold produced by its evaporation is almost imperceptible and consequently the differenee of temperature, which in proportion to its amount is able to affect the density of the air, will be quite inappreciable.

In order to make this cooling and these differences sensible we must accelerate the evaporation. But as I wish to make these experiments in the open air, I cannot employ for the acceleration either heat or an artificial dryness. There remains, then, only the rapidity of renewing the air of which I can make use for my purpose.

Happily, this means has succeeded very well.

I fixed the bulb of a thermometer in the center of a wet sponge, and then suspending the thermometer by a string, whirled it through the air with great velocity. In this way I obtained a fall of temperature amounting at times to eight degrees, Reaumur, a quantity much larger than those that have been obtained by other processes and more than sufficient to manifest the influence of agents capable of modifying the cooling. But I ought to give my process in detail for the benefit of physicists who may wish to repeat or improve on these experiments. The frame of the thermometer chosen for the experiment ought not to extend further than an inch above the bulb, because whenever the sponge touches the frame, the latter raises its temperature about two or three degrees. The other end of this frame ought to have a ring or a solid hook to which can be attached a string of at least a twelfth of an inch in diameter. I make this string of such a length that the distance from the cen-

ter of the circle which it describes in whirling to the middle of the thermometer bulb, is just thirty inches. At first I held this string by the hand, but the friction that the cord undergoes in whirling against the fingers holding it, wore it so fast, that one day it broke during the experiment, the thermometer went off on a tangent, rose to a great height and was broken in its descent.

Since then I have used an iron swivel. This consists of a handle that I hold in my hand, and an arm three inches long which turns freely and at right angles with the end of the handle. The string is fixed to a ring which is at the end of this arm. The friction then takes place on the metal, and consequently the string does not become worn and is in no danger of breaking.

To determine the velocity with which the thermometer turns, I have endeavored to give it as many revolutions in a minute as I am able, that is about 140. Thus, the thermometer bulb traverses in a minute 140 times the circumference of a circle five feet in diameter; this gives it a velocity of thirty-six to thirty-seven feet per second.

But before beginning the experiment, it is necessary to know the temperature and humidity of the air in which the experiment is to be made. For this purpose I have another thermometer, also of small bulb and uncovered, and whose readings agree with the one to be swung.

I suspend this thermometer with a hygrometer in the open air on a small post very near the place where I am about to make the experiment and at such a height that the thermometer bulb and the hygrometer are at the level of my head while swinging the sling thermometer.

When this thermometer that I call "stationary" has attained the air temperature, I begin to whirl the sling thermometer, but at first entirely uncovered and dry, in order to ascertain the average temperature of the air which it meets in its revolutions; this temperature sometimes differs a little from that of the stationary thermometer and I record it as well as that of the stationary thermometer,

I then place the bulb of the sling thermometer in a small sponge in which I have made a hole for receiving it and in such a manner that the bulb rests in the center of the piece of sponge; I tie the sponge with a string above the bulb.

The sponge thus tied and entirely soaked with water ought to have the shape and size of a sphere, 10 to 11 lines in diameter. This done I heat or cool the wet sponge until the temperature of the bulb attains precisely the same point which it would have by turning entirely uncovered through the air.

At the moment when the temperature is stationary at this degree, I whirl the thermometer with the velocity that I have determined and stop it an instant, first every minute, then every half minute, to observe its rate of cooling. I continue the whirling until the temperature begins sensibly to rise, the lowest point that it has attained is therefore that which indicates the amount of cooling produced by evaporation. At the moment when the experiment is finished I observe the hygrometer and the stationary thermometer in order to take account of the change which may have taken place in the air during the experiment.

I ought to say further that when the wind blows, one must place himself so that the plane of the circle described by the thermometer may be parallel to the direction of the wind, because then there is a compensation; if the relative velocity of the thermometer is greater whilst it goes against the wind it is so much the less when it moves in the same direction with it. By taking all these pains we obtain such an exactness that if anybody repeats the experiments several times under the same circumstances he will obtain results of which the differences will not be over two-tenths of a degree.

Results of experiments made on the Col du Géant with the thermometer *tournant*:

	Thermometer.	Differences.	Reading of the Hygrometer.	Absolute Dryness.	Differences.	Degree of Cooling	Differences.
1.	8.1		57.0	6.7998		7.5	
2.	7.7	0.4	58.0	6.6785	0.1213	7.1	0.4
3.	5.65	2.05	84 3	2.3286	4.3499	2.35	4.75

Results of the same experiment made at Geneva:

	Thermometer.	Differences.	Reading of the Hygrometer.	Absolute Dryness.	Differences.	Degree of Cooling*	Differences.
1.	16.8		51.0	7.4788		8.1	
2.	16.3	0.5	70.8	4.5695	2.9093	5.7	2.4
3.	3.6	12.7	91.2	1.0824	3.4871	1.0	4.7

If in these experiments we regard the cooling as a measure of the evaporation and apply the same calculation to these results as has been done for evaporation of still water, calling x the amount of evaporation or the cooling produced by a degree of heat and y the quantity produced by a degree of dryness, we shall find:

On the mountain $x = .780$
$y = .725$

In the plain $x = .151$
$y = .799.$

We see at once in these experiments, as in the preceding, that the effect of heat is very much greater on the mountain than in the plain. But what is most remarkable is that, on the mountain as well as the plain, the action of dryness, compared with that of heat, is much greater in this accelerated evaporation than in evaporation from still water.

In the latter case we obtained on the mountain $x = 4.188$ and $y = 1.386$, and consequently the effect of dryness was only a third of that of heat. Whereas in the accelerated evaporation, where $x = 0.780$ and $y = 0.725$, these two differences are nearly equal.

Likewise in evaporation, from still water on the plain, we had $x = 1.938$ and $y = 2.775$; consequently the influence of dryness did not exceed a third that of heat, whilst in the accelerated

* This column shows that the greatest cooling that I have obtained at Geneva by this process is only 8.1. But we know that at Benares the evaporation of water from a vessel of porous earth exposed to a dry wind causes the temperature of the water to fall from 100 to 58 degrees Fahrenheit or from 30 2-9 to 16 of the Reaumur scale. This is a cooling of 14 2-9 R.; but it is attained by starting from a very high temperature and, perhaps, also from an extreme degree of dryness.—Phil. Trans, 1793, p. 130.

evaporation, when $x = 0.151$ and $y = 0.799$, the influence of dryness is five times as great.

We can, therefore, assert that whether on the mountain or the plain, when the air is renewed with a velocity of 36 to 37 feet per second, the influence of the dryness of the air on the evaporation becomes almost three times what it is when the same air is quiet. The reason of this fact is not difficult to comprehend. In quiet evaporation, the layer of air next to the body in which the water evaporates absorbs the vapors arising from it and so soon loses the advantages of its dryness.

But when this air is renewed, its opportunity to become humid is diminished, and the more rapidly it is renewed the less is the opportunity afforded; thus the effect of its dryness is increased. Another observation that had escaped me, but has not escaped M. Trembley, to whom I have communicated these results, is that the acceleration of the motion diminishes the advantages which dense air has over rare air with respect to dryness.

I will explain myself.

The dryness of the air always increases the evaporation to a greater extent in the plain than on the mountain. But when the air is violently agitated this superiority of the air is diminished, and the effect of dryness approaches more of an equality at the two stations. This phenomenon is entirely in accordance with those that have already been mentioned.

In short, we have seen that the density of the air increases the effect of its dryness. Now the air is compressed at the front of a body which strikes it or which it strikes, and this compression is proportionally greater in rare air than in dense air; for example, if the densities of two columns of air are in the ratio of two to three, the same force which will double the density of the first, will increase the density of the second by only two-thirds, whence their densities will become respectively four and five; thus the more these columns of air are compressed the more nearly equal will become their densities.

Accordingly, as the motion is more rapid, the more nearly will the effect of dryness on the mountain equal that on the plain.

ATMOSPHERIC ECONOMY OF SOLAR RADIATION.*

By Arthur Searle, with Comments by Professor Ferrel.

The terrestrial atmosphere acquires energy from the solar radiation by direct absorption, by the absorption of terrestrial radiation, and by conduction from terrestrial solids and liquids. It loses energy in three corresponding ways; by radiation into space, by downward radiation, and by conduction.

As some time must elapse between the acquisition and the loss of any given amount of energy, the air always contains a certain accumulated store of activity resulting from the solar radiation, and manifested in warmth, expansion, and movement. It is a general and apparently well founded belief, the reasons for which need not here be repeated, that terrestrial temperatures are maintained to a great extent by the aid of this atmospheric accumulation of energy; so that a far lower temperature would prevail in the absence of the air. The hypothesis which has been current until recently with regard to this protective action of the atmosphere depended upon a supposed effect of selective absorption, which has now been largely, if not entirely, disproved by Langley's experiments. The supposition, indeed, was always somewhat difficult to reconcile with the familiar fact that celestial bodies appear redder at a small than at a great altitude; since, so far as the visible spectrum is concerned, this proved that among the constituents of the atmosphere there were some, abounding in its lower strata, which absorbed radiations of small wave-length more readily than the others. Hence it did not seem probable that the radiation from terrestrial substances the temperature of which was far below red heat would be absorbed by the air with peculiar readiness, and thus prevented from escaping into space. This reasoning, however, could not be conclusive, and actual experiment was required to overthrow the assumption that the air was much more transparent to solar than to terrestrial radiation.

As we are now obliged to abandon this assumption, it is nat-

*From the Proceedings of the American Academy.

ural to inquire whether the known phenomena of conduction will suggest a better explanation of the protective action of the atmosphere than can be afforded by the observed laws of absorption and radiation. By conduction, fluids acquire heat most readily when hot bodies are applied to their lower surfaces, in consequence of the convection currents thus established. On the other hand, the application of cold bodies to their lower surfaces, as it does not originate such currents, withdraws their heat only by the much slower process of conduction through their own substance.

Hence, an undisturbed atmosphere will acquire heat more readily by contact with warm ground than it loses heat by contact with cold ground. Part of the heat thus acquired might have been conducted to adjacent portions of the ground in the absence of the atmosphere, but another portion would have been directly radiated into space. It now becomes a question whether the atmosphere thus heated will discharge its recently acquired energy by radiation into space as readily as the ground would have done in the absence of an atmosphere.

Without undertaking to decide this question, it will here be assumed that the heat acquired by the atmosphere from warm ground will not be radiated as readily as it would have been radiated by the ground itself. Since it will not be readily lost by conduction, in the absence of violent agitation of the air, for the reason already given, the hypothesis seems admissible that it tends to accumulate, and to increase the stock of energy contained in the atmosphere much more efficiently than can be done by the processes of absorption and radiation.

If we admit the existence of this tendency, we have next to consider what natural provision can be suggested for checking its effects when they have attained a certain magnitude; for it is obvious that they do not increase indefinitely. If we suppose atmospheric energy to be manifested only as heat, its accumulation would ultimately be checked by an increasing radiation from terrestrial solids and liquids; if manifested only by expansion, it is perhaps possible that portions of the atmosphere would be driven off into space, carrying away the energy

mechanically; but a more immediate check is afforded by that portion of the accumulated energy which displays itself as atmospheric movement. When the winds have attained a certain degree of violence, they disturb the portions of the air which would otherwise remain stagnant over the colder parts of the ground, and the process of heating the atmosphere from beneath gradually ceases to retain sufficient advantage over that of cooling it from beneath to permit a further accumulation of energy.

If a permanent increase should take place in the amount of solar radiation, it is clear, upon the present hypothesis, that some time would elapse before the increasing agitation of the atmosphere put an end to the increase of its energy. The stock of atmospheric energy in general, and that part of it manifested as heat, would thus be permanently increased. The terrestrial temperature would be raised, tempests would be more frequent and severe, and the entire atmosphere would probably occupy more space.

On the other hand, a permanent diminution in solar radiation would tend to diminish the agitation of the air, and, although the terrestrial temperature would decline, this loss of temperature would not be so great as that which would have occurred if the winds had maintained their previous force. The atmosphere, accordingly, acts as a check upon extreme variations of heat and cold; when little heat is received, it will be better economized than when the supply of heat is excessive, although particular regions may have, in the former case, a very severe climate.

The observed association of extreme cold with still air, and the greater violence of tempests in the heated portions of the world, on the whole, are among the facts tending to support the hypothesis above explained.

In the present discussion, the consequences resulting from the compressibility of the atmosphere have thus far been neglected, and what has been said above would be equally applicable to an atmosphere wholly incompressible. But in such an atmosphere the distribution of heat would materially differ from

that actually observed. As a convection current rises, the air composing it expands, from the removal of pressure, and its energy largely ceases to exhibit itself as heat. Under these circumstances, the solid and liquid particles carried up with it are reduced in temperature, and made less capable of radiation into space than before. It may likewise be supposed, indeed, that the expanded air itself will have its previously small capacity for the discharge of its energy into space still further diminished. The additional tendency to retain energy, thus suggested, would demand more consideration if the discharge were effected by any process of the nature of conduction; that is, if the outer surface of the atmosphere were chiefly instrumental in the process. In this case, the expansion of the ascending air would be a highly important means of delaying the escape of energy received by conduction from warm ground; and an incompressible atmosphere might not in any considerable degree protect the planet which it surrounded.

However slightly the expansion of ascending currents may check the escape of energy, it is certain that the subsequent descent of the air composing them must exhibit more and more of its remaining energy in the form of heat. This phenomenon is generally recognized by recent writers upon meteorology, and there can be little doubt that it powerfully affects the relative climates of places at different altitudes. The climate of an elevated region is colder than that of the sea-level, because a smaller part of the atmospheric energy appears there as heat, and a larger part as expansion. Whether this is a sufficient explanation of the observed difference of climate can scarcely be determined until we have more knowledge with regard to the actual extent and velocity of the convection currents of the atmosphere.

The considerations above set forth indicate the conclusion, that the effect of conduction, aided by convection currents, is probably an important means of maintaining the present terrestrial temperature, as well as the present distribution of warmth in different latitudes and at different elevations. If this conclusion should hereafter find a more satisfactory basis in observa-

tion and experiment, it would have some interesting applications to the climate of the larger planets. Their extensive atmospheres, subjected to a powerful force of gravitation, may perhaps enable them to economize very efficiently the comparatively small quantity of solar radiation which they receive. Another branch of inquiry connected with the same general subject relates to the conditions of temperature in different parts of the ocean. The atmospheric and oceanic currents prevailing in former times are also frequently discussed by geologists. If the atmospheric convection currents have the effects here attributed to them, they may help to account for some of the unexplained phenomena of prehistoric climates, the evidences of which have remained to the present day.

PROFESSOR FERREL'S COMMENTS.

The principal point in Mr. Searle's paper seems to be that heat is transferred by conduction and convection from the earth's surface up into the atmosphere, which, at least when pure and dry, is a comparatively poor radiator, and so the earth is kept at a higher temperature than it otherwise would be, since the heat does not escape with the same facility as it would if radiated directly from the earth's surface through the atmosphere. This he regards as an assumption merely, but I think it is correct, and the effect, as far as it goes, as stated. I do not think, however, that there can be much effect from this circumstance, for the capacity of the air for heat being very small, especially by volume, the heat carried away directly from the earth's surface is very small, the greater part being that in the form of latent heat in the vapor of the atmosphere. This heat is absorbed at the earth's surface in evaporation and disengaged again in condensation up in the atmosphere at different altitudes, where it is radiated with less facility, by direct radiation than from the earth's surface. It is, however, radiated above a considerable part of the atmosphere, and so escapes through the balance with greater facility than it would from the earth's surface, and so this in some measure counteracts the protective effect arising from the less facility of escaping from the *earth*

into space. The whole amount of heat conveyed away from the earth's surface in the form of latent heat, is perhaps about one-tenth of that received from the sun and absorbed, and so radiated again into space. If this one-tenth part only has a little less facility for escaping into space than it would have if radiated directly from the earth's surface, I do not think that the protective effect can be very much.

Mr. Searle assumes, as has usually been done, that the earth's mean temperature would be much lower than it is, if it were not in some way protected by the atmosphere; but this, in the present state of our knowledge with regard to the laws of radiation and absorption, is by no means certain. Knowing the true value of the solar constant and the law of radiation, we can readily determine what would be the temperature of a body with a lampblack surface, or rather with a surface which is a perfect absorber, placed at the distance of the earth from the sun; for we have only to determine the temperature which it must have to radiate as much heat into space as it receives from the sun. With a solar constant of 2.5, and even one considerably greater, Dulong and Petit's law would make the temperature of that body fall considerably below the mean temperature of the earth, and so it would need some protective effect from an atmosphere to keep it up to this temperature. But by Stefan's more recent law, the body, with a solar constant of 2.5, would stand at a temperature considerably above the mean temperature of the earth, and so it would not need a protecting atmosphere to keep it up to this temperature.

With the old idea of equality of the relative radiativities and absorptivities of bodies at all temperatures for each of the rays of different wave-lengths, what is stated above with regard to a body which is a perfect absorber would be true of all bodies, and so of the earth, but we now know that this equality takes place only where the radiator and absorber have the same temperature. With the earth receiving mostly the rays of the shorter wave-lengths from the sun, and radiating mostly rays of the longer wave-lengths, we might conceive such an arrangement of selective absorption and radiation that the

mean temperature of the earth would be what it is even by Dulong and Petit's law without a protecting atmosphere. This, for instance, might be the case if the earth's surface were of such a nature, say, as to absorb nearly as many of the shorter wave-lengths as a lampblack surface, and to radiate less than half as many as such a surface of the longer wave-lengths. But if the radiations and absorptions for all wave-lengths were in the same proportion to those of a lampblack surface as one-third or one-half, or, in other words, if there was no selective absorption or radiation, then the temperature of the body would be the same as that with a lampblack surface.

In the present state of our knowledge, therefore, with the uncertainty of the law of radiation deduced from higher temperatures only, in its application to lower temperatures, we cannot say whether the earth needs any protection from an atmosphere to keep it up to its observed mean temperature.

WM. FERREL.

CORRESPONDENCE.

A STATIONARY DUST-WHIRL.

TO THE EDITORS.—In reading in the June number of the JOURNAL of M. Faye's whirlpool theory of storms, I am reminded of a curious phenomenon which I did not witness, but which was described to me by a friend for whose reliability I can vouch. It happened in the village of Portland in this state, about 12 or 14 years ago. I can not quote my friend's exact language, but will describe it as nearly as possible as he described it to me. My friend said that on a hot, dry, still and cloudless summer day he was standing on the sidewalk in the said village of Portland looking at the dusty street, when he saw a little commotion in the dust a few yards in front of him. Looking at it closely, he saw that a little whirlwind had just started in the dust and he expected to see it move off along or across the street, but to his surprise it did not do so but continued in the same spot. The dust commenced to rise and assume

the form of a funnel which stood straight up and the apex remained in the same spot while it spun around like a top. The dust raised higher and higher until it reached a height, he thought, of 200 or more feet, and then the whirlwind seemed to gradually die out at the bottom while the dust over head continued for a little while to move around in a large circle, but finally, after two or three minutes, it all died out and the dust settled down again. The only thing strange or interesting about it is the fact that the apex of the little whirlwind did not progress in any direction, but remained perfectly stationary while it lasted. My friend's theory was that the whirlwind commenced in the dust of the street and gradually rose, which theory, if correct, would go a little way to disprove M. Faye's whirlpool theory. But there is no certainty that my friend's theory is the correct one, for if it was a whirlpool which started above and the apex descended, as there was no clouds, mist or dust in the atmosphere to form a visible funnel, there was nothing to attract attention to it until the apex reached and disturbed the dust of the street.

WARREN HOPKINS.

Algonac, Mich., June 25, 1889.

CURRENT NOTES.

THE JUDGES OF THE TORNADO ESSAYS.—We take pleasure in announcing that Professor Davis of Harvard University, Professor Ferrel and Dr. Mendenhall, superintendent of the Coast Survey, have consented to act as judges of the tornado essays. We think the competitors may feel well assured of competency and impartiality on the part of these gentlemen.

HIMMEL UND ERDE.—This is the title of a new popular scientific monthly journal of most unusual merit. The tenth number (for July) contains an article on the advance in selenography by Dr. Weinek, the conclusion of one on the recent theories of atmospheric electricity by Professor Sohncke, an article on the zodiacal light, by Mr. O. T. Sherman, and one on the Norwegian North Sea Expedition by Professor Mohn. In

addition to this it has many shorter communications and bibliographical notes. The Journal is exquisitely gotten up, is finely illustrated, and contains monthly 64 pages. We can commend it to those of our readers who enjoy science in the German language.

A Differential Barometer for Altitudes.—Director Cruls, of the imperial Brazilian observatory at Rio Janeiro, has invented a differential barometer which is of a novel character. A U-shaped tube has each arm terminate in an air-tight box of known capacity, provided with a stop-cock. If the U be partially filled with a suitable liquid and both cocks are opened, the height of the liquid in the two arms will be the same. If now the cocks be closed, and the instrument be taken to a station of different elevation and only one of the cocks be opened, the closed box will retain the air-tension of the first, the open, that of the second stratum. The level of the liquid will now be different in the two arms by a height which will depend on the difference of pressure at the two stations.

A light liquid, like water, can be employed, and yet the instrument may be kept of convenient size. If the stop-cocks are small, they may be opened alternately, each just long enough to partially equalize the difference of pressure in the boxes. With each opening, the level of the ends of the liquid columns is to be read off, and the sum of the differences measures the difference in pressure.

Locomotives and Moisture.—A correspondent of the *Northwestern Railroader* advances a curious theory for the increasing prevalence of floods and rain-storms. He says that there are over 30,000 locomotives in use in North America, and estimates that from them alone over 53,000,000,000 cubic yards of vapor are sent into the atmosphere every week to be returned in the form of rain, or over 7,000,000,000 cubic yards a day,—"quite enough," he says, "to produce a good rainfall" every twenty-four hours. Estimating the number of other non-condensing engines in use as eight times the number of locomotives, the

total vapor thus projected into the air every week in this country amounts to over 470,000,000,000 cubic yards.

Thus says *Public Opinion:* It is a clever idea, but what does its inventor mean by a "cubic yard of vapor"? A cubic yard of vapor in the boiler and piston is one thing, in the free air at temperature 70° it is another, and at temperature zero, still another. If instead of vapor we take the water from which it is made, we will easily see that the "shower of rain" per day would not well water a county. The water used by a locomotive in a run of 50 miles would barely well wet down a small lawn, and that employed in a run of 1,000 miles would hardly serve to keep a five acre lot in good condition. If the steam from 240,000 steam engines were confined to an area a few miles square, it might, if other conditions were favorable, cause a shower every day, but when it is given off over half of North America, its results in increasing the humidity would be so small as to utterly escape detection.

THE CHAMSIN.*—Dr. Schneider spent two years at Ramle, near Alexandria, in Egypt, and while there made a study of the Chamsin, a hot wind so-called from its occurrence during about fifty days in the spring. Its season falls in the period of about fifty days from the latter half of March to the early part of May; only within this time is the desert wind felt frequently in lower Egypt, though it occurs sometimes at later dates. The frequency and duration of its visits within the above period are not fully determined, but from four to six Chamsins are commonly noted in every season. The wind usually lasts three days, whence the saying, "it comes one day, it stays one day, and it goes one day." During the daytime, it blows briskly and steadily, but weakens generally at night. Its source is in the desert, as is indicated by its direction from the southeast or south southeast. Its temperature is less than that of the Samum (simoom): the latter has been recorded as 132° F. in the desert; but the former has a maximum of 110° at Cairo and of 105° at Alexan-

* Notes from an essay on "Der Chamsin und sein Einfluss auf die niedere Thierwelt," by Dr. Oskar Schneider; Festschrift, Verein für Erdkunde zu Dresden. 1888, 93-113.

dria. This record shows that the Chamsin extends with but little diminished intensity to the coast of the Mediterranean.

During the presence of the wind, the air is very dusty and the sun is obscured or hidden. Even when no wind is blowing, as shortly after a Chamsin, the "Chamsin air" is spoken of. Daylight is so far dimmed that Dr. Schneider suggests that the Biblical expression, "Egyptian darkness," may be derived from this characteristic feature of Chamsin days: but the only moderately dusty air of the Chamsin is not to be confused with the heavy clouds of dust that are carried in dust-storms or squalls. The Chamsin air seems to be electrified; for while the wind is blowing, the hands and face smart as if pricked with sharp needles.

The Chamsin is one of those winds of uncertain relationship to which special attention may be profitably directed. From its occurrence after dewy nights, from its relatively brief duration and semi-periodic occurrence, and from its similarity to the Sirocco, I am inclined to associate it with cyclonic winds; regarding it as a member of the cyclonic indraft to which special characteristics are given by reason of the geographic peculiarities of its path. It may be noted than van Bebber (Witterungskunde, ii, 279) describes a path frequented by cyclones in spring on the southern borders of Europe. If these cyclones cause the Chamsin, then we should expect to find a Sirocco in Tunis and southern Italy a day or so before a Chamsin was felt in lower Egypt. W. M. D.

International Meteorological Congress.— The French Meteorological Society, wishing to profit by the presence of numerous scientists during the Exposition of 1889, decided to convoke an international meteorological congress at Paris, as it had already done in 1878. The committee on the organization of the Congress, composed partly of members of the Council of the Meteorological Society, has prepared a list of questions which can be advantageously discussed; it was decided that the Congress should be held at Paris, September 19–25, and that

each member's assessment should be twelve francs, which also entitles him to the report of the papers presented, to be published after the Congress.

French and foreign meteorologists interested are requested to inform the president of the committee as early as possible, of the subjects which they wish to discuss, as well as of new questions to introduce in the programme.

The Committee of Organization has these officers:

President. M. Renou, President of the French Meteorological Society, and Director of the Observatory of the Park of St. Maur, (address 7 Rue des Grands Augustins, Paris).

Vice-Presidents. M.M. E. Becquerel, Daubrée, vice-admiral Cloué.

General Secretary. M. L. Teisserenc de Bort, General Secretary of the Meteorological Society.

Treasurer. M. Angot, Titular Meteorologist at the Central Meteorological Office.

Secretaries. M.M. Moureaux, Lasne.

The following programme is proposed for discussion:

Pressure. On the reduction of the barometer to sea-level. Verification of the relation between the velocity of the wind and the barometric gradient.

Temperature. Comparison of observations made under different shelters with those made with the sling thermometer. Measurement of the decrease of temperature with height. Distribution of solar heat over the globe. Secular changes of climate.

Winds. Choice and graduation of anemometers. Results of the recent determination of the vertical component of the wind.

Aqueous Vapor. Measurement of water in the liquid state suspended in the atmosphere. Precise measurement of evaporation on different surfaces.

Clouds. State of the cirrus observations in the various countries. Measurement of the height of clouds. Photography of clouds. Classification of clouds and definition of nimbus.

Precipitation. What progress has been made in the measurement of dew and very light rains. Distribution of rain on the

ocean. Studies of floods and warnings of them in the various countries.

Influence of Cosmical Phenomena. Atmospheric tides, lunar, solar, etc. Influence of sun-spots on the meteorological elements. Various lunar influences.

Weather Forecasts. Investigations for the improvement of weather forecasts.

Miscellaneous Phenomena. Measurement of the intensity of solar radiation; actinometry. Atmospheric polarization. Transparence of the atmosphere for the differet rays of the spectrum. Twinkling of stars. General optical phenomena.

Magnetism. Relation of magnetic phenomena to earthquakes. Magnetic disturbances and sun-spots. Study of earth-currents. Magnetic observations at sea.

Electricity. Discussion of methods of observing atmospheric electricity. Summing up the observations. Relation of electricity to the other meteorological elements. Aurora borealis.

Thunder-storms. Study of thunder-storms; recent progress in it. Barometric oscillation during thunder-storms.

Applied Meteorology. Phenological phenomena as related to the meteorological elements. Migration of birds; appearance of insects. Applications of meteorology to agriculture and hygiene.

Climate of Puebla, Mexico.—The interesting and attractive city of Puebla lies about 76 miles southeast of the city of Mexico, and 25 east of the volcano of Popocatapetl. It is 2167.75 m. above the sea level, or at about the elevation of Santa Fé, in New Mexico. Meteorological observations have now been carried on in this elevated tropical city for 10 years, and from their discussion by Senor Enrique M. Cappelletti, S. J., in the *Boletin Mensual*, we are able to present some notes on the climate of Puebla.

The mean pressure is 594. 2 mm. This reduced to sea level is 764 mm., about 2 mm. higher than is given for that region by Dr. Hann in his atlas. The oscillation of the barometer is slight, the entire range in the 10 years (1877 to 1886) being only 12. 9

mm. The barometer ranges highest in July instead of January as with us. Other Mexican stations have a similar barometric maximum, as the city of Mexico, Leon, Guanajuato, and Mazatlan, but in all except Guanajuato it is the lesser of two annual maxima, the greater is in or near winter.

The temperature undergoes but moderate change: the extreme maximum in 1878, was 34.7° C., the extreme minimum — 1.7° C. in 1877. The maximum mean temperature falls in June, and the thermic seasons do not correspond exactly to the astronomic ones. The warmest season is in April, May and June, and in this peculiarity, Puebla is like other Mexican points, as can be seen in the following table in which the means are given in centigrade degrees:

THERMIC SEASONS IN MEXICO.

Season.	Months	Puebla.	Leon.	Mexico.	Guanajuato.
Warmest	April, May, June.	18.20	22.2°	18.0°	21.1°
Temperate	July, August, September.....	17.0	20.2	16.5	19.3
"	October, November, December	16.3	17.7	14.9	17.3
Coldest	January, February, March.....	12.5	14.8	12.5	14.6

In the City of Mexico the maximum temperature falls in April. In Mazatlan, on the Pacific coast, and opposite Cape St. Lucas, the maximum falls in July, as with us. Mazatlan is in *tierra caliente.*

From a study of the subject Sr. Cappelletti concludes that this advance of the summer into the months usually claimed by spring is characteristic of Mexico outside of the *tierra caliente.* This is very interesting as it is the reverse of what happens in the northeastern states, especially in the region of the great lakes, where winter lingers in the months nominally vernal.

The reason of this advance of summer is, we think, not far to seek. The region in question would have its highest temperature, naturally, about or soon after the sun passes through its zenith, but in this case the heavy rains occur about the same time. There is comparatively little rain until June, but from then until October the rains are abundant and often heavy. The

advancing maximum of temperature is cut off by the heavy rains and consequent evaporation. It is probable that farther study of the problem will show that the advance of the summer is not so noticeable north of Zacatecas, where the summer rains are not so marked. Also, probably a similar advance of summer will be found in all northern sub-tropical regions where the summer rains are heavy. Sr. Cappelletti suggests some relation between the prevailing easterly upper air currents in summer and the cooler summer weather. These upper air currents are said to be variable until July. We fancy that the summer rains may depend more or less on them and so the relative coolness of the summer months, but the latter only through the former.

The relative humidity is very variable, the lowest observed is 0.07, the highest 0.99; the mean is 0.57. The rainfall has averaged 1.2 meters, of which about three-quarters falls from June to September, inclusive. The rains are sometimes excessively heavy, for a brief time, and seem to be derived from local rather than general storms. In 1887, the rainfall was $2^{m}.5$, more than twice the average. The midsummer lull of precipitation, to be expected here, is scarcely, if at all, appreciable at Puebla. Absolutely clear days are not especially common here, the average being only 41 in the year, or less than one a week.

Sr. Cappelletti ends his discussion by the suggestion of a law "that when the barometer and thermometer run parallel, both rising or both falling, in the traces of monthly or annual means, it is evidence that unusual meteorological phenomena will follow." He instances the parallelism of the traces for 1882 and 1883 at Puebla, followed in 1884 and 1885 by unusual temperature disturbances and rains, and notes that the parallelism of 1885 and 1886 was followed by even more unusual phenomena in 1887, not ended apparently when his report was drawn up.

REPERTORIUM FÜR METEOROLOGIE BAND XI, ST. PETERSBURG, 1888.—This seems to be an interpolation volume in the series which has biennially received an addition; for it was only the previous year that volume X appeared, and there have already been issued most of the separate parts of volume XII.

Or, are Director Wild and his assistants preparing so many important papers that hereafter we may expect annual volumes in the Repertorium series? If so they will be gladly welcomed by the meteorological world.

The present volume is of unusual interest to meteorologists, for, unlike most of the numbers which usually have about half the space given to discussions of magnetic observation, it is almost entirely devoted to meteorology.

The following is the table of contents:

No. 1. B. Sresnewskij — The mean distribution of air pressure in European Russia for 1881–1885, (with three charts). 70 pages.

No. 2. M. Rykatschew — The distribution of wind and of air pressure on the Caspian Sea (with 6 charts). 61 + XXXVI pages.

No. 3. A. Schönrock — The Thunder-storms of Russia in 1885 (with one plate). 37 pages.

No. 4. H. Abels — Re-organization and work of the Meteorological-Magnetic Observatory at Katherinenburg in 1885 and 1886. 62 pages.

No. 5. W. Friedrichs — Investigation of the capabilities of action of a Richards Thermograph (with 2 plates). 41 pages.

No. 6. B. Kiersnowsky — On the question of predicting the temperature minimum. 15 pages.

No. 7. W. Dubinski — Comparison verification of two anemometers at Hamburg (Deutsche Seewarte) and at St. Petersburg (Central Phys. Obs.). 16 pages.

No. 8. A. Schönrock — On the method of computation and the reliability of mean air pressure from aneroid barometers. 16 pages.

No. 9. P. Brounow — Comparison of normal barometers of some of the most important meteorological institutes of Europe (1 plate). 17 pages.

No. 10. W. Friedrichs — Investigation of the capabilities of action of a Richards Barograph (1 wood-cut). 32 pages.

No. 11. R. Rosenthal — The wind-relations at St. Petersburg. 30 pages.

No. 12. A. Schönrock—Contribution to the study of thunder-storms in Russia (1 plate). 18 pages.

No. 13. E. Berg — The significance of the absolute humidity for the origin and movement of thunder-storms (1 plate). 19 pages.

No. 14. H. Wild — On the winter Isotherms of East Siberia and the increase of the temperature with the elevation for these.

Minor communications:

I. M. Marks — Climate of Enisseisk according to 12 years observations, 1871–83—page 1.

II. A. Schönrock — Contribution to the verification of pocket aneroids under the air-pump—page 27.

III. A. Schönrock—On the question of the definition of "Silver-thaw" (Rauhfrost) and "glazed-frost" (Glatteis)—page 36.

IV. H. Abels — The elevation above sea-level of the barometers of some meteorological stations in West Siberia—page 43.

V. R. Bergmann — The travel journal of Ferdinand Von Wrangell for the winter 1823–24—page 49.

The papers on the Richards Barograph and Thermograph, the comparison of the Combe's anemometer testers at Hamburg and St. Petersburg, reliability of aneroid barometers, and the international comparison of normal barometers, are most important additions to our knowledge of meteorological apparatus. In no place is more careful work done, in the way of the study of meteorological and magnetic instruments, than is carried on at St. Petersburg and Pawlowsk under the direction of Professor Wild, and if any such investigations can be considered authoritative, we know of none that can be more safely relied on than those published from time to time in the "Repertorium." The only objection that can be urged against these St. Petersburg investigations is, that relations observed at such a high latitude (60°) are not always found to be identical with those of the lower latitudes where most of the meteorological observations are made.

So few of these "Repertorium" volumes come to America that it is probably not generally known to our meteorologists

that either the complete volumes or the single papers can be obtained through the authorized agent, Voss' Sortiment (G. Hassel) in Leipzig, or they may be ordered through book importers in this country.

Detailed reviews of some of the papers found in the present volume will probably be given in future numbers of this journal. F. WALDO.

ROYAL METEOROLOGICAL SOCIETY.—The usual monthly meeting of this Society was held on Wednesday evening, May 15, at the Institution of Civil Engineers, 25 Great George Street, Westminster, Dr. W. Marcet, F. R. S., President, in the chair.

Mr. T. H. Hall was elected a member of the Society.

The following papers were read:

1. "Account of some experiments made to investigate the connection between the Pressure and Velocity of the Wind," by Mr. W. H. Dines, B. A., F. R. Met. Society. These experiments were made for the purpose of determining the relation between the velocity of the wind and the pressure it exerts upon obstacles of various kinds exposed to it. The pressure plates were placed at the end of the long arm of a whirling machine, which was rotated by steam power. The author gives the results of experiments with about twenty-five different kinds of pressure plates. The pressure upon a plane area of fairly compact form is about 1½ lbs. per square foot at a velocity of 21 miles per hour, or, in other words, a pressure of 1 lb. per square foot is caused by a wind of a little more than 17 miles per hour. The pressure upon the same area is increased by increasing the perimeter. The pressure upon a ¼ foot plate is proportionally less than that upon a plate either half or double its size. The pressure upon any surface is but slightly altered by a cone or arm projecting at the back, a cone seeming to cause a slight increase, but a rim having apparently no effect.

2. "On an improved method of preparing ozone paper and other forms of the test, with starch and potassium iodide," by Dr. C. H. Blackley, F. R. Met. Society. Some years ago the author made some experiments with the ordinary ozone test

paper, but found that the papers did not always give the same result when two or more were exposed under precisely the same conditions. He subsequently tried what reaction would take place between unboiled starch and potassium-iodide when exposed to the influence of ozone, but the difficulty of getting this spread evenly upon paper by hand so as to insure a perfectly even tint, after being acted upon by ozone, led him to devise a new method of accomplishing this. Briefly described it may be said to be a method by which the starch is deposited on the surface of the paper by precipitation, and for delicacy and precision in regulating the quantity on any given surface leaves very little to be desired.

3. "Notes on the Climate of Akassa, Niger Territory," by Mr. F. Russell, F. R. G. S. This paper gives the results of observations made from February, 1887 to October, 1888, at Akassa, which is the seaport and principal depot of the Royal Niger Co., and is situated at the mouth of the River Nun, in the Niger Delta.

4. "Wind-storm at Sidney, New South Wales, on January 17, 1889," by Mr. H. C. Russell, F. R. S.

Royal Meteorological Society.—The last meeting of this society for the present session was held on Wednesday evening, the 19th of June, at the Institution of Civil Engineers, 25 Great George Street, Westminster, Dr. W. Marcet, the President, in the chair.

Mr. F. J. Moss-Flower, Mr. A. H. Halder, Mr. R. A. Naylor, and Mr. C. B. Penlington were elected Fellows.

Mr. W. Marriott gave a very graphic and interesting account of the recent thunder-storms which have prevailed over this country. On Sunday, June 2d, a thunder-storm passed across the country in a northerly direction from Wiltshire about 3 A. M., and reaching Edinburgh by 10:44. It travelled at the rate of about 50 miles an hour. It is possible that this storm traveled still further north and reached Kirkwall at 3:37 P. M. A severe thunder-storm prevailed over the neighberhood of the Tweed between 11 A. M. and noon, and was accompanied by hail of very large size, some of the stones being 5 inches in circum-

ference. A very destructive storm occurred over the whole of the Northwest of England and South of Scotland during the afternoon, much damage was caused by lightning and very large hail fell over an extensive area. Some of the hailstones measured 7 inches in circumference and weighed 7 ounces. During the night of the same day a severe thunder-storm prevailed over Norfolk, which was also accompanied by very large hailstones, some of which were 5 to 6 inches in circumference. On Thursday, the 6th, thunder-storms prevailed during the afternoon over the whole of the Southeast of England. That which passed over the Metropolis about 9 o'clock was remarkable for the brilliant and continuous display of lightning. During the same night and on the early morning of the following day a very destructive storm prevailed over the Eastern Counties, much damage being done by the lightning in the Northwest of Norfolk. Severe hail-storms occurred between 2 and 3 A. M. both at Margate and Ipswich. During the afternoon of the 7th, destructive thunder-storms prevailed over the whole of the Southern Counties, much damage being done by lightning, while at Tunbridge Wells there was a most remarkable hail-storm. One of the hail stones which was weighed was actually half a pound in weight.

An interesting collection of over 40 photographs of lightning taken during the storm of June 6th was also exhibited to the meeting, in addition to the sinuous, ribbon and meandering flashes of lightning, several photographs showed knotted, multiple and dark flashes. The following papers were also read:

"The Climate of British North Borneo," by Mr. R. H. Scott, M. A., F. R. S.

"On the Variation of the Temperature of the air in England during the period of 1849 to 1888," by Mr. W. Ellis, F. R. A. S., F. R. Met. Soc.

"Atlantic Weather and Rapid Steamship Navigation," by Mr. C. Harding, F. R. Met. Soc.

"Meteorological Phenomena observed during 1875-87 in the neighborhood of Chelmsford," by Mr. Henry Corder.

"Rainfall in China, and Meteorological Observations made at Ichang and South Cape in 1888," by Dr. W. Doberck, F. R. Met. Soc.

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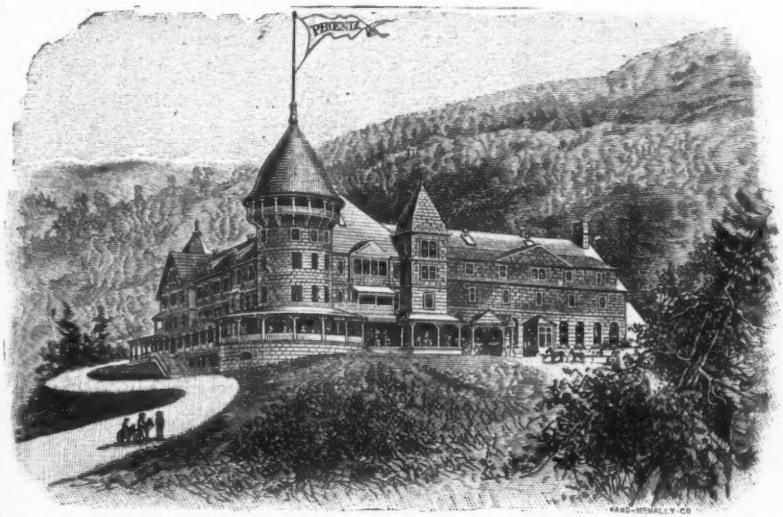

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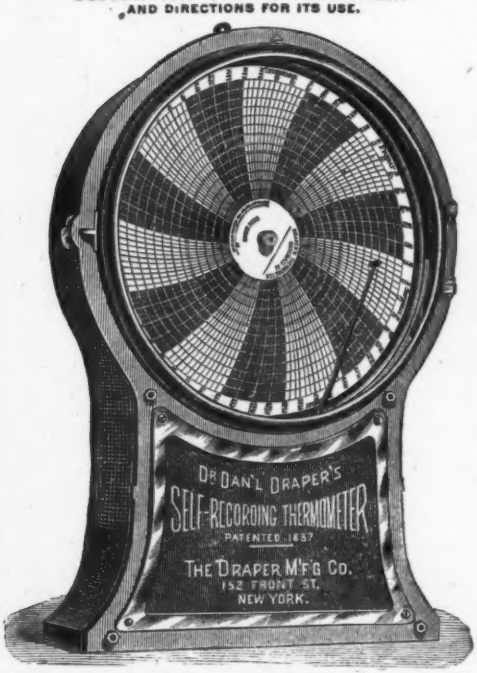

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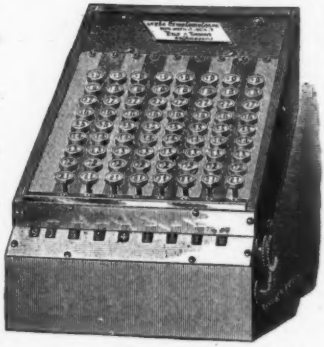

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